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ABSTRACT

This paper, presented at the 1979 meeting of the American Educational Research Association (AERA) in San Francisco, discusses the effects of calculator availability on the elementary school mathematics curriculum. The rationale for a shift from a computationally based curriculum to a conceptually oriented curriculum utilizing the calculator as an instructional tool is presented. Recommendations for curricular change and the teaching of complex computations in the elementary school are also included. (HM)

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Calculators in the Classroom: A Proposal for Curricular Change

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Historical perspective

A careful study of the history of Mathematics Education will reveal that computation has always been the focus of the elementary school mathematics curriculum. In the eighteenth century days children were taught ciphering. Rote computation was taught without any attempt to develop an understanding of the process. During the nineteenth century there were a few persons like Warren Coburn calling for attention to meaning but the curriculum remained computational. During the 1930s there was a movement toward social utility and developing meaning in mathematics. Then in the period from 1958 to 1971 there was an emphasis on teaching the structure of mathematics. Viewed from the perspective of today, there was one unfortunate aspect of the so called "modern mathematics" movement. Much attention was given to rationalizing algorithms. Each of the complex algorithms, e.g., the division algorithm was taught in great detail using a subtracting approach so that students would understand why the algorithm worked. But computational algorithms are nothing more than a set of rules for efficient paper and pencil answer finding.

While it is important for students to understand the mathematics they are learning, time spent teaching children why algorithms work does little to help pupils understand mathematics and its applications. Vestiges of this unfortunate curriculum trend remain in current textbooks. Since 1971 there has been a well defined swing toward the "Basics". In

elementary school classrooms, this has been interpreted as more emphasis and time teaching basic facts and computation with even less time for concepts and applications.

Throughout the eras described above, the curriculum has remained computational. There is great contrast between the recommendations of leading mathematics educators and practices in the classroom.

At the same time this country was experiencing a Back-to-Basics movement in the 70's, advances in electronic technology were reshaping the mathematical needs of society. Today the availability of inexpensive calculators has eliminated the need for complex computational algorithms. Before calculators (B.C.) it was necessary to be proficient in computations to apply mathematics. That has now changed. Cash registers show the amount of change and nearly every home and office has a calculator which can perform complex computations rapidly. It is quite ironic that as the calculator availability was reducing the need for computation, schools were increasing their emphasis on paper and pencil computation proficiency.

The current status of the elementary school mathematics curriculum

A study of currently available elementary school mathematic texts suggests that the curriculum is computationally oriented. A typical fifth grade text devotes 139 pages (37%) to computation. However, teachers do not teach all the chapters. For a number of reasons decisions are made to omitt certain chapters.

Most classes cannot finish the text in the time alloted for mathematics. In practice, the chapters omitted are usually noncomputational. Chapters covering geometry, measurement, probability, statistics, and problem solving are first targets for omission. The highest priority is given to teaching computation. In fact, while certain topics are omitted, daily work is supplemented with additional computational worksheets. In many classes, computation completely dominates the year's work. My experience and that of my colleagues observing in schools almost daily for an entire school year suggests that computation is the major emphasis of nearly every classroom. Calls for accountability and minimal compentency testing have increased the time spent teaching computation since parents and school boards want to be sure that children know their "Basics". The newer texts reflect this trend.

The proposal

1. Shift from a computationally based curriculum to a conceptually oriented curriculum utilizing the calculator as an instructional tool.
2. Eliminate the teaching of complex computations in the elementary school.

Rationale

1. We cannot afford the cost in time of teaching complex computations.

Through surveying teachers, observing, and analyzing textbooks, I have concluded that more than two years of the first nine school years studying mathematics are devoted to teaching the division algorithm. When the level of proficiency attained by the pupils is considered along with this information, I conclude that we can no longer afford to teach complex long division. An analysis of other computational procedures will reveal that the cost benefit ratio is far too high. The time saved by dropping this topic could be devoted to applications and problem solving where the focus would be on when to divide not how to divide.

2. Complex computations by paper and pencil are no longer necessary.
3. A computationally oriented curriculum inhibits the development of problem solving. A heavy emphasis on algorithmic thinking tends to encourage the application of rule seeking behavior even when it is not appropriate. Successful problem solvers need to try a variety of approaches, apply heuristics, and recognize that more than rule identification is required. With a calculator to perform computations, pupils are freed to focus on the problem rather than being distracted by switching to algorithmic thinking to compute.
4. The NAEP data suggests that 13-year-olds are not proficient in complex computations, even with all the time devoted.

An examination of the National Assessment Data (Carpenter, Coburn, Reys, & Wilson, 1978) reveals that less than two-thirds of the 13-year-olds could perform a long division problem (three digit by two digit). Only 45% of the 13-year-old sample could solve a single step word problem requiring single digit division.

5. Other topics are of more importance.

In order to use mathematics meaningfully in today's society an understanding of certain other topics is important. More attention should be given to estimation, interpreting data, geometry, measurement, and the use of decimals and percents. Time will be available for these important topics only if computation is deemphasized.

Recommendations for curricular change

Specifically, I am proposing that the following complex computations be excised from the curriculum.

1. Division with two or more digits in the divisor (e.g., $37\overline{)296}$).

This topic comsumes more time than any other single computational topic in the elementary school curriculum. On the other hand, the single digit divisor algorithm is relatively easy to teach and could be retained. It is critically important that pupils learn the meaning of division. This can certainly be accomplished with single

digit divisor computation. While I am recommending that calculators be used to perform complex divisions, attention should be given to interpreting quotients and estimating results. It is essential that children attach meaning to their calculator results. Calculator activities have been published which focus on this objective (Vervoot, Reys, et.al., 1979).

2. Multiplication by two or more digits (e.g. $\begin{array}{r} 462 \\ \times\ 89 \end{array}$).
   Children should gain proficiency with problems such as

   $\begin{array}{r} 326 \\ \times\ 8 \end{array}$ and $\begin{array}{r} 39000 \\ \times\ \ 4 \end{array}$.

3. Addition of fractional numbers with unlike denominators.
   This topic has proven to be one the most difficult and thus time consuming topic in the curriculum. The difficulty may result from the cognitive demands of the task. Addition of fractional numbers requires formal thought and most elementary school pupils have not reached this cognitive level. This skill can probably be taught more efficiently if begun in the junior high school.
4. Complex computations with decimals.
   Such tasks as 3.45 x .865 or 456.78 ÷ 6.7 are more appropriately performed on a calculator.

What should we teach?

I will not attempt to describe a new curriculum in detail but instead make certain clarify points related to the proposal.

1. Insist on mastery of basic facts.

   It is important that children memorize the addition and multiplication facts. As Professor Schoen has shown, the calculator can be quite useful in teaching the basic facts.

2. Stress the concepts of addition, subtraction, multiplication, and division. It will be easier to do this if less emphasis is placed on computation.

3. Stress estimation and mental arithmetic.

   With calculators used for complex computations there is much importance in children being able to estimate the answer, to judge whether the result makes sense. Along with this more time teaching mental arithmetic would be quite useful.

4. Emphasize applications.

   Mathematics is studies in large part because of its utility. Yet the curriculum has not included much attention to applications for two reasons. We have reasoned that pupils need to learn to compute before they can apply mathematics and time has not been available because of the emphasis on computation. This must change.

5. Emphasize decimals.

6. Be sure that topics such as measurement, statistics, probability, and problem solving are taught.

   These topics have appeared in elementary school texts but have been given low priority. They should be considered as basic.

7. Include computer literacy.

   Since computers play such a central role in today's society, children should begin to learn about them at an early age.

The NCSM list of 10 basics (1977) should become the foundation for curriculum development. Number ~~nine~~ five on the NCSM list is "appropriate computational skill." This paper suggests one interpretation of this statement.

The role of the calculator

Although this proposal seems to stress the calculator as a substitute for paper and pencil computation, the calculator is actually a highly versatile instructional aid. A calculator can be used in concept development quite effectively since many examples can be explored quickly. Consider the concept of prime number. A number can be tested for primeness quickly by dividing on a calculator. Pupils must know what divisors to try but the focus can remain on prime since the child does not have to take the time to perform the paper and pencil division. The concept of decimals can be introduced quite early and developed through calculator activities. More realistic numbers can be used since the calculator handles "grubby" numbers just as well as "nice" numbers. Many motivational calculator games develop important concepts such as place value, estimation, integers, and functional rules.

Summary

The curriculum changes I am proposing may seem radical but the mathematics needs of society have changed in the last few years with the advent of electronic technology and will change even more in the near future. A computationally oriented curriculum is archaic and will not prepare our students for the 21st century. We must shift the emphasis to applications and topics that now are crowded out by the time spent on computation. Only by excising complex computations can time be made available for applications, problem solving and other important topics. Such changes have far reaching implications, from teacher education to textbook preparation.

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